

VARIABLE LOCATION OF PUNISHMENT IN A RESPONSE SEQUENCE¹

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Key pecking of pigeons under a fixed-ratio 100, grain reinforcer schedule was followed by electric shock occurring once in each sequence of 100 responses with the shocked response varying irregularly in successive sequences. Under this shock schedule, a localized suppression of responding in a response sequence was not correlated with the probability of shock at different points in the sequence. High shock levels increased the duration of post-reinforcement pauses and suppressed responding during the first half of the response sequence. This suppression often persisted after the shocked response when shock occurred early in the sequence. The shock schedule did not produce a consistent suppressing effect on responding during the last half of the response sequence.

In their review of studies of punishment, Azrin and Holz (1966) pointed out the inadequacy of any general statements describing the effects of punishment on behavior because the temporal pattern of punished responding depended on the particular reinforcement schedule maintaining the performance and also on the schedule of punishment. The specific effects of different punishment schedules have been demonstrated for behavior maintained by a fixed-ratio (FR) reinforcement schedule, under which reinforcement occurs after a fixed number of responses. The bi-valued response rate generated by FR schedules, consisting of a pause after reinforcement followed by a high and regular rate of responding throughout the reinforced response sequence, persists under a variety of conditions including punishment of every response (Azrin, 1959b). However, scheduling punishment at a particular locus in each reinforced response sequence will differentially modify the pattern of responding in the sequence (Dardano, 1970; Dardano and Sauerbrunn, 1964a; Dardano and Sauerbrunn, 1964b; Holz, 1967; Lyon, 1964). The findings of these studies reveal some consistent relations: responses prior to the site of punishment in the response se-

quence are suppressed to a greater extent than the punished response; post-punishment responses in the sequence are resistant to suppression; the increase in duration of post-reinforcement pauses is related to the proximity of punishment to the beginning of the sequence; and the responses at the beginning of the sequence are more easily suppressed than responses near the end of the sequence.

The present study examined the effects of punishing a response in a reinforcement sequence of 100 responses when the response scheduled for punishment varied unsystematically in successive sequences rather than remaining the same in each sequence. The schedule of punishment in this case was a variable-ratio (VR) schedule under which one response in each reinforced sequence of 100 responses was punished following a variable number of responses having a mean of 50. Punishment of a response in each sequence was inevitable as in earlier studies, but the particular response followed by shock can be considered unpredictable.

METHOD

Subjects

Three adult male White Carneaux pigeons included B-34 and B-53, with experimental histories of fixed-ratio schedules with a food reinforcer and response-dependent shock, and B-55, an experimentally naive pigeon. Throughout the study, each pigeon's weight was maintained at 80% of its average free-

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feeding weight determined before the study. Grit and water were available continuously in the individual home cages.

Apparatus

The experimental chamber was 15 in. (38 cm) high, 13 in. (33 cm) long and 13 in. (33 cm) deep. A Gerbrands pigeon key having an operating force of approximately 20 g (0.196 N) was mounted behind a 0.75-in. (1.9-cm) aperture in the center of the work panel, 10 in. (25.4 cm) above the grid floor, and was transilluminated by two white lights (GE 313). A relay behind the front panel produced auditory feedback with each key peck. Two lights (GE C 7.5 w) provided ambient illumination in the chamber, and a speaker on the front panel delivered masking noise. A grain mixture was presented for 3.5 sec by a dispenser centered below the response key and 3 in. (7.6 cm) above the grid floor. The chamber was inside a sound-attenuating compartment equipped with a fan for air ventilation.

A 50-msec pulse of 60 Hz ac was delivered to the pigeon by silver electrodes implanted around the pubis bones (Azrin, 1959a). The shock circuit included a step-up transformer, auto-transformer, milliammeter, and fixed resistors totalling 30,000 ohms. Intensity of the shock pulse was scheduled by shorting the shocker output and pre-setting the intensity on the milliammeter. Electrical impedance was measured by a bridge circuit using a 7-v 60-Hz input and ranged from 700 to 2000 ohms.

A tape reader scheduled a single shock in each FR 100 after one of 19 possible responses that were multiples of five in the FR 100: the fifth response, the tenth, . . . ninety-fifth. The order of the punished responses in successive sequences was derived from a table of random numbers with two restrictions: the same response was not punished more than twice successively, and each of the 19 punishment locations was represented an equal number of times in a series of 300 shock locations. During the study, the tape was reversed at the end of the series, resulting in 600 shock deliveries before the series was repeated. The electromagnetic scheduling and recording equipment was located in an adjacent room.

Procedure

An experimental session terminated after 2 hr or after 40 scheduled reinforcements,

whichever occurred first. The 40 reinforcements permitted an approximate maintenance of the experimental weight of each pigeon, and post-session feeding adjusted the weights upward. The weight and the electrical impedance of each pigeon was determined before and after each session. Sessions were conducted daily for B-53 and B-55 and six days a week for B-34.

The pigeons were exposed to the FR 100 reinforcement schedule for a minimum of 30 sessions and until no trends were apparent over 10 consecutive sessions in the measures of overall response rate (responses in a session divided by session duration), running rate (responses in a session divided by session duration excluding duration of pauses after reinforcement), average pause after reinforcement duration, average time to complete the first half of the sequence, and the average time for the last half of the sequence. Subject B-34 required 68 sessions; B-53, 67 sessions; and B-55, 37 sessions. After stabilization of the performance, the shock condition, which consisted of a single response-dependent shock occurring once in each sequence in accordance with the VR 50 shock schedule, was scheduled concurrently with the FR 100 food reinforcement schedule. The shock intensity was initially 2 mA and was increased by 1 mA increments for B-53 and B-55 and in 2 mA increments for B-34. A given intensity of shock was scheduled until the previously noted measures of performance appeared stable over five successive sessions. The mean number of sessions under a shock level was 12.3 for B-34, 14.4 for B-53, and 16.4 for B-55. The maximum shock intensity was the level under which the pigeon failed to complete more than two sequences totalled over five successive sessions, which defined complete suppression. These maximum levels were 20 mA, 18 mA, and 14 mA for B-34, B-53, and B-55 respectively. Following complete suppression, the shock schedule was discontinued, and sessions under the FR 100 food schedule were continued for each pigeon until performances like those before addition of the shock schedule were recovered and stabilized.

Interresponse time (IRT) distributions for responses occurring before shock and those occurring after shock in each sequence were recorded for B-34 in 10 sessions before the addition of the shock schedule and in 10 sessions under a shock intensity that markedly

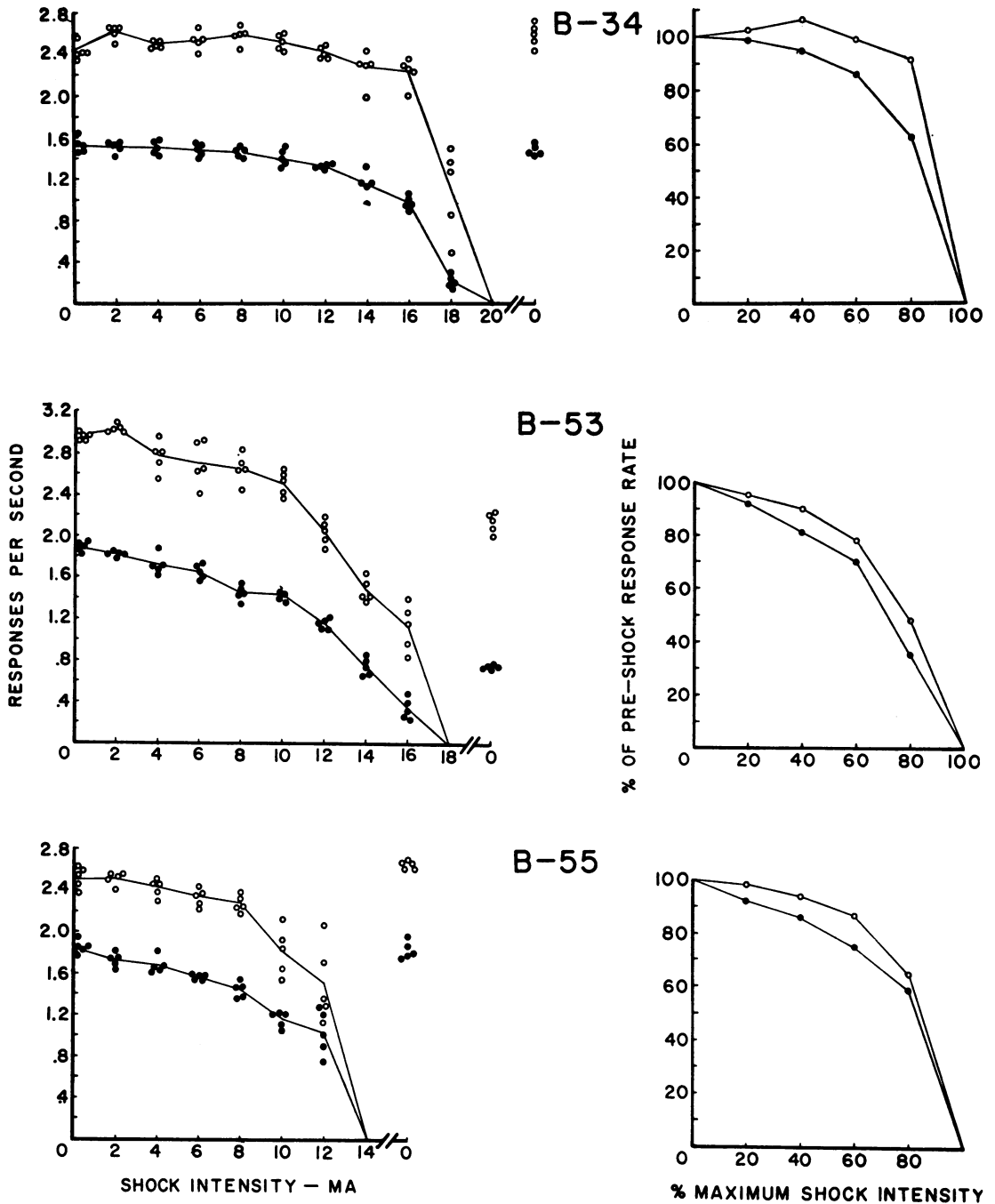


Fig. 1. Overall response rate (solid circles) and running rate (open circles) as a function of shock intensity for each pigeon. The graph on the left for each pigeon shows these rates in each of the final five sessions under each shock intensity and in the final five sessions before addition of the shock schedule and after removal of the shock schedule. Response rates under no-shock are shown as 0 mA. The arithmetic means of each set of five values are connected. The graph on the right for each pigeon shows selected values from the left graph with response rate expressed as a per cent of the mean rate before addition of the shock schedule and shock intensity expressed as per cent of the maximum intensity scheduled for the pigeon.

suppressed responding. Distributions for B-55 were obtained during a second exposure to the shock schedule in which the shock intensity was increased from 2 to 8 mA in 2 mA steps with a few sessions under the lower shocks intensities and 20 sessions under 8 mA. The distribution included 19 class intervals, and interval size was 0.2 sec. IRT distributions were not included for B-53, which failed to recover its no-shock overall and running rates after complete suppression.

RESULTS

Figure 1 shows the overall response rate and the running rate as a function of shock intensity. The left graph for each pigeon presents these rates in each of the final five sessions under each shock level; the right graph shows the same functions with selected transformed values to emphasize the general form of the functions and to facilitate intersubject comparisons. The transformed data were obtained by expressing each mean response rate as a proportion of the mean rate before addition of the shock schedule and each shock intensity as a proportion of the maximum intensity, then determining the relative rate under 0.2, 0.4, 0.6, and 0.8 of the maximum intensity.

The concave downward relationship between the response rates and shock intensity illustrates the resistance of the response sequence to a rate reduction under lower shock levels. A marked reduction in rate for all pigeons occurred only after the shock level exceeded 50% of the maximum intensity, then the rates decreased rapidly with further increases in intensity. Other properties of the performances seen in Figure 1 include: (1) the similar shapes of the functions for overall rate and running rate; (2) a decrement in overall response rate appearing before a decrement in running rate, indicating a lengthening of the post-reinforcement pause duration as the initial effect of the shock schedule; (3) the lack of a general facilitation of responding under low-intensity shock; (4) the greater variability among the five-session response rates, especially running rate, under higher shock levels; and (5) after complete suppression, B-53's failure to recover the response rates that had been present before scheduling the shock condition. Regarding this last point, observation of B-53 revealed a stereotyped and

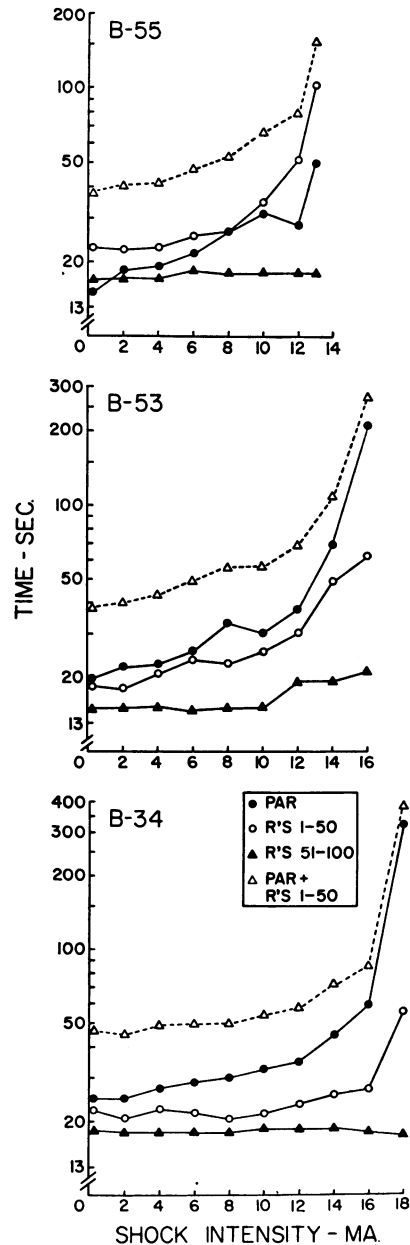


Fig. 2. Average elapsed time of pause after reinforcement (PAR), the first 50 responses in the sequence (Rs 1 to 50), and the final 50 responses in the sequence (Rs 51 to 100) as a function of shock intensity. The function combining post-reinforcement pauses and the first 50 responses (PAR + Rs 1 to 50) is the sum of the individual functions. Ordinate scale is logarithmic. Data based on the final five sessions under each shock level. Each point is the mean of the five session means. Data from the first sequence and any incomplete sequence in the session were excluded. The highest shock intensity listed for each pigeon was that intensity under which at least 11 sequences were completed in each of the final five sessions.

repetitive postural movement that occurred before starting the response sequence, and, to a lesser degree, between responses during the initial part of the sequence.

Figure 2 summarizes the elapsed time for sub-parts of the response sequence as a function of shock intensity. Each graph includes average duration of the post-reinforcement pause (PAR), average time to complete the first half of the sequence (Rs 1 to 50), average time to complete the last half of the sequence (Rs 51 to 100), and the summated average time for post-reinforcement pause and the first half of the sequence (PAR + Rs 1-50). The shock condition markedly increased both the duration of the pauses after reinforcement and the time to complete the first half of the sequence but did not have a consistent suppressing effect on responding during the last half of the sequence. The functions for pause after reinforcement (PAR) and for the first half of the sequence (R's 1-50) are generally, positively accelerated. In those cases where a data point in either the "PAR" function or the "Rs 1 to 50" function for a pigeon was lower than the preceding point, the corresponding point in the other function always was higher than the preceding point by an equal or greater amount. As a result, a point in the "PAR + Rs 1 to 50" function was always equal or greater than the preceding point. This relation is illustrated in Figure 2 by the data for B-55 at 12 mA. Also, Figure 2 shows the increase in the duration of the post-reinforcement pause under 2 mA or 4 mA, which was the first consistent effect of the shock condition.

The time required to complete each response sequence also was partitioned into elapsed time for responses preceding shock (excluding the post-reinforcement pause time) and elapsed time for responses following shock. Figure 3 shows the average time to complete the pre-shock and post-shock segments of the sequence as a function of shock intensity. The data are from the same sessions shown in Figure 2. The total frequency of pre-shock and post-shock responses were similar when averaged over five consecutive sessions. The two values in the graph for performances without the shock condition, 0 mA, were obtained during sessions with the shocker disconnected.

Intense shock produced a greater suppressing effect on responses before shock relative to

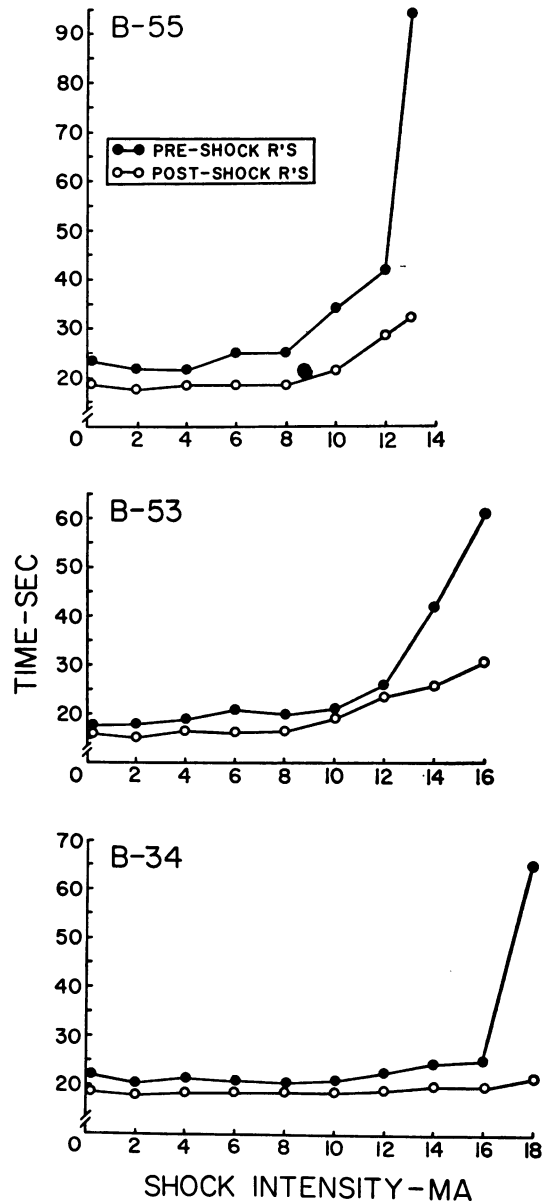


Fig. 3. Average time to complete the pre-shock responses in each sequence and the average time to complete the post-shock responses in the sequence as a function of shock intensity. Comparable segments under no-shock are included at 0 mA. Each point is the arithmetic mean of the values from the final five sessions under each shock intensity. Data from the first sequence and any incomplete sequence in each session were excluded. Criterion for the highest shock intensity same as in Figure 2.

responses after shock. For each of the pigeons, the average time for pre-shock responding under the highest shock level increased at least three-fold compared to this response seg-

ment under no-shock. The time required to complete the post-shock segment of the sequence also increased for all pigeons, although the increment of 2.4 sec was slight for B-34. These functions further reveal that before addition of the shock condition, all pigeons completed the segment of the sequence corresponding to post-shock responses faster than the segment corresponding to pre-shock responses and that this original difference did not widen appreciably until the maximum or a near-maximum shock intensity was scheduled. These results, in conjunction with those

in Figure 2, show that the major suppressing effect of shock was exerted on the pre-shock responses in the first half of the response sequence.

The IRT distributions recorded for B-34 and B-55 provided further data on the effects of the shock schedule on pre-shock and post-shock responding in the sequence. In sessions when shock was not delivered, the IRT distribution of "pre-shock" responses showed greater variability and a higher median value than the IRT distribution of the "post-shock" responses. Under a shock intensity that clearly

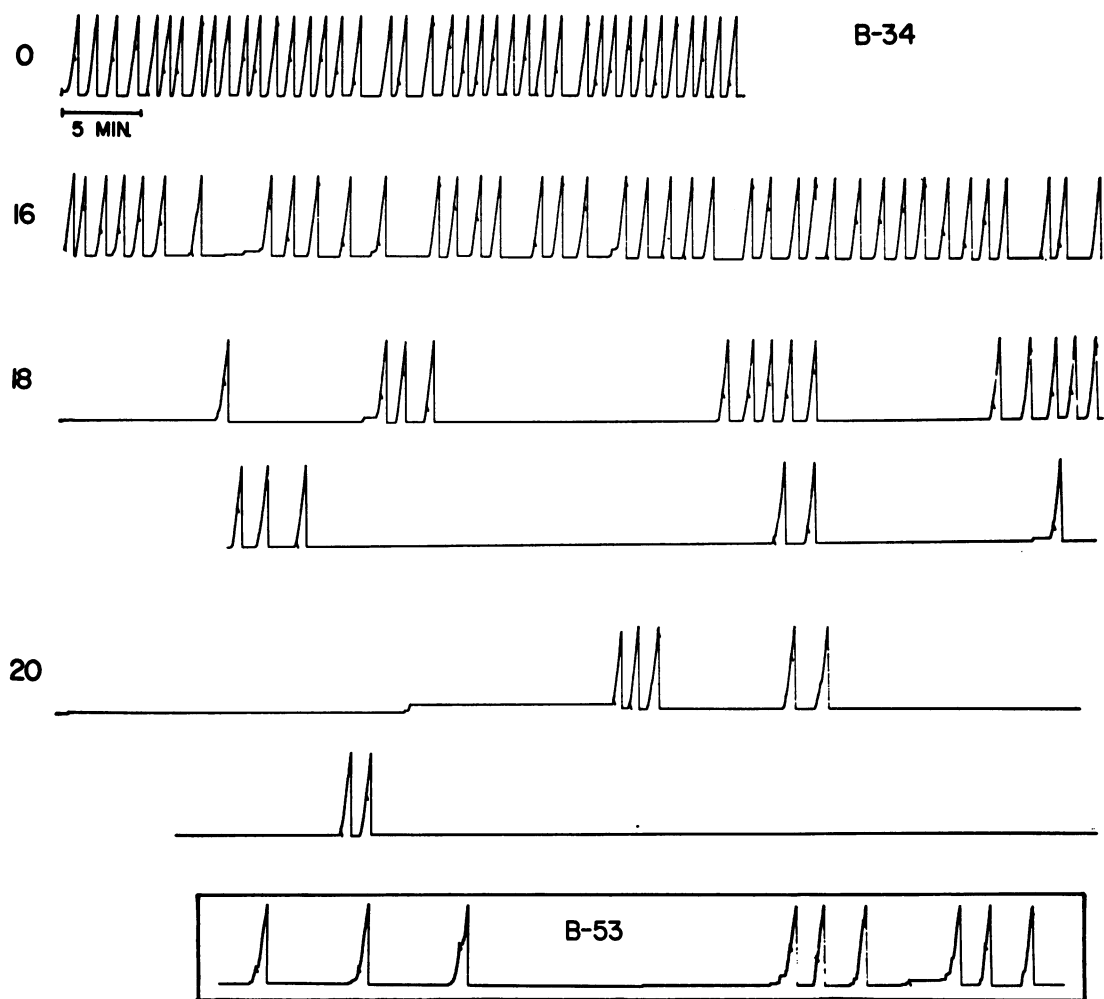


Fig. 4. Cumulative response records for B-34 showing representative performances under different shock intensities and an excerpt for B-53 under 16 mA. Complete sessions are shown for B-34. The indented records are continuations of the upper record. The number listed at the beginning of each record denotes shock intensity in mA for that session. Top record (0) is the final session before addition of the shock schedule, second record (16) illustrates the first consistent and marked effect of the shock schedule, the third record (18) illustrates the performance under the highest intensity that did not completely suppress responding, and the lowest record (20) shows a performance during the transition to complete suppression.

suppressed responding, the variability and median value of both IRT distributions increased, more so for the pre-shock distribution than the post-shock distribution. The increased variability of the IRTs under shock reflected a lower proportion of IRTs in the modal interval, 0.2 to 0.4 sec; the initial occurrence or the increased proportion of IRTs in the highest interval, greater than 3.6 sec; and the initial occurrence of IRTs in the lowest interval, 0 to 0.2 sec. These brief IRTs represented double pecks, which usually occurred early in the sequence.

The cumulative response records in Figures 4 and 5, for B-34 and B-55 respectively, show some sample performances that illustrate the various changes in the temporal properties of responding produced by the shock condi-

tion. The records for each pigeon under the highest intensity that still permitted on-going responding, 18 mA for B-34 and 13 mA for B-55, reveal the inter-subject variation in the degree of disruption by the shock schedule, ranging from the single response break early in the sequence for B-34 to the frequent breaks and irregular responding during the first half of the sequence for B-55. The records for B-55 under the higher shock intensities demonstrate a relation between the disruption of post-shock responding in the sequence and the disruption of responding early in the sequence. If the pattern of responding was irregular immediately after starting the sequence and shock was delivered after one of these early responses, responding was usually disrupted after shock; if the response pattern was regular at the be-

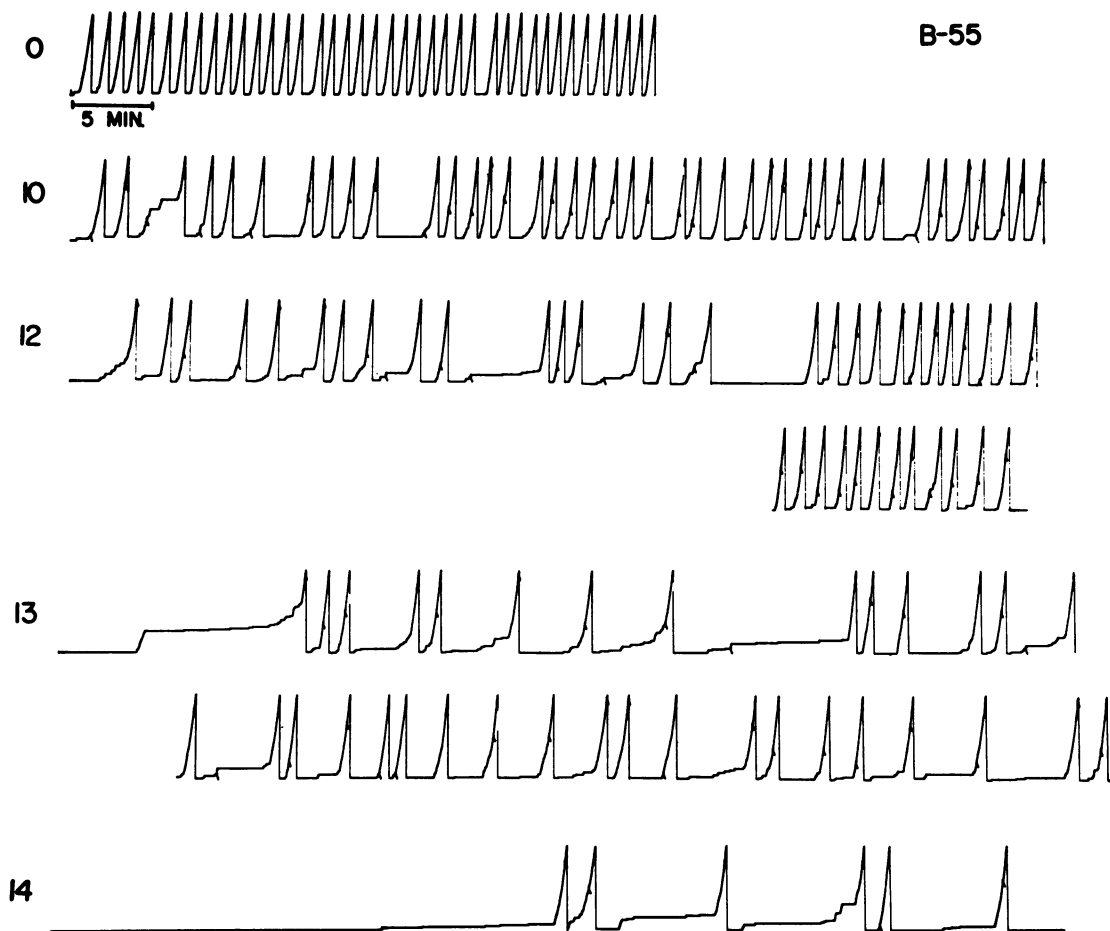


Fig. 5. Cumulative response records for B-55 illustrating a performance under no shock (0), the initial marked effect of shock (10), a strongly suppressed performance (12), a performance under the highest intensity that did not completely suppress responding (13), and a performance during the transition to complete suppression (14).

ginning of the sequence, post-shock responding was not disrupted following shock early in the sequence.

The excerpt from a cumulative record of B-53, shown at the bottom of Figure 4, illustrates a unique reaction of this pigeon under the shock condition: a local pause after the shocked response in the sequence. Under intermediate shock levels, this pause occurred only after shocked responses early in the sequence; under higher shock levels, the pause also appeared in the last half of the sequence. Responding in the last half of the sequence subsequent to the post-shock pause was unaffected. This pause was responsible for the increase in time required to complete the last half of the sequence seen in the graph for this pigeon in Figure 2. Some other characteristics of the performances seen in these records are the absence of intra-session recoveries under the higher shock intensities, the extensive disruption of responding during the first sequence of the session under high shock intensities, the occurrence of sequences with a short pause after reinforcement and little or no disruption of responding under the maximum shock intensity, and the absence of any typical temporal pattern of suppressed responding within the sequence.

DISCUSSION

The pattern of suppressed responding in the response sequence under the VR punishment schedule was unrelated to the changing probability of shock during the sequence. At the beginning of the sequence, each of the 19 potentially shocked responses had the same probability of being shocked; then, as these responses were completed without being shocked, the probability of shock on the remaining responses increased. For example, probability of shock on the fifth response was 0.053; if half of the sequence was completed without shock, probability of shock on the fifty-fifth response was 0.11; and if shock had not occurred after the ninetieth response, the ninety-fifth response would be shocked. However, suppression of responding was highest at the beginning of the sequence when probability of shock was minimum, and a general suppression of responding never occurred in the second half of the sequence. This lack of correspondence between local rate of responding

and immediate likelihood of shock points to an interaction between the effects of the shock schedule and the reinforcement schedule. Presumably, the controlling factors associated with the FR 100 reinforcement schedule were decisive determinants of the locus of disruption in the response sequence. The vulnerability of responses early in the sequence to a suppressing effect of shock follows from the interpretation of responding under FR schedules by Ferster and Skinner (1957). They consider the response sequence to be a chain, with number of completed responses acting as both a discriminative stimulus and a conditioned reinforcing stimulus, with a gradient of conditioned reinforcing strength increasing with response number. The pattern of suppressed responding also suggests that the VR shock schedule exerted a generalized suppressing effect over the entire sequence, rather than a local effect reflecting the immediate probability of shock. This average effect would parallel the control by VR schedules of positive reinforcement that generate uniform response rates without any marked variation of local rate with response number (Ferster and Skinner, 1957).

Under the VR shock schedule used in this study, the occurrence of shock in each sequence was a discriminative stimulus for reinforcement without further shock; yet, the performances of two pigeons often showed a continuation of disrupted responding after a shocked response if shock occurred early in the sequence. This post-shock disruption was absent in studies where the same response(s) in each sequence was followed by shock: shocking the first response under an FR 50 reinforcement schedule resulted in an immediate shift to a high terminal rate after shock (Dardano and Sauerbrunn, 1964*b*); shocking the initial third of the sequence under an FR 60 or FR 99 reinforcement schedule resulted in a high rate following the first nonshocked response (Dardano, 1970). This difference in post-shock responding under variable and fixed shock loci in the sequence might also be related to the number of responses after shock that were required to complete the sequence.

A further difference between the performances under the VR shock schedule and under a fixed locus of shock was the local rate immediately preceding the shocked response when shock occurred near the end of the sequence.

On those occasions when shock occurred on the ninety-fifth response under the VR schedule, the immediately preceding responses were never suppressed, whereas shocking the final response under an FR 50 often disrupted responding during most of the sequence (Dardano and Sauerbrunn, 1964b) and shocking the final third of the sequence under an FR 60 or an FR 99 reinforcement schedule occasionally disrupted responding just prior to the initial shocked response (Dardano, 1970). Again, these studies are not directly comparable, and the differences under the fixed and the variable shock loci might reflect factors associated with the size of the FR schedules or a unique effect of shocking the reinforced response. Concerning the latter possibility, Church (1969) reported no difference in degree of suppression when the reinforced response or the response preceding the reinforced response was shocked under an FR 10 reinforcement schedule.

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